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Author(s): Pabian, Frank V.
Coblentz, David

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Surface Disturbances at the Punggye-ri Nuclear Test Site: Another Indicator of Nuclear Testing?

Frank Pabian and David Coblenz

Abstract

A review of available very high-resolution commercial satellite imagery (bracketing the time of North Korea's most recent underground nuclear test on 9 September 2016 at the Punggye-ri Underground Nuclear Test Site) has led to the detection and identification of several minor surface disturbances on the southern flank of Mt. Mantap. These surface disturbances occur in the form of small landslides, either alone or together with small zones of disturbed bare rock that appear to have been vertically lofted ("spalled") as a result of the most recent underground explosion. Typically, spall can be uniquely attributed to underground nuclear testing and is not a result of natural processes. However, given the time gap of up to three months between images (pre- and post-event), which was coincident with a period of heavy typhoon flooding in the area¹, it is not possible to determine whether the small landslides were exclusively explosion induced, the consequence of heavy rainfall erosion, or some combination of the two.

Background

The Democratic People's Republic of Korea (DPRK or North Korea) has conducted five acknowledged underground nuclear tests at the Punggye-ri Nuclear Test Site at the foot of Mt. Mantap (2205 meters elev.) in North Hamgyong province in the northeast of the country. Those tests have generally been increasing in explosive yield,² with the most recent, which occurred on 9 September 2016, the largest to date, estimated to have been roughly 20 kilotons equivalent of chemical explosives. Previously reported physical observable evidence of North Korean underground nuclear testing include the detected seismic signals from all five tests, and some detected escaped radionuclides from the 2006³ and 2013⁴ events. However, physical evidence in the form of visible surface disturbances (e.g., landslides or spall) has not been reported previously.

The Punggye-ri underground nuclear test site is imaged periodically (with fair regularity, roughly on a monthly basis) by high resolution electro-optical commercial observation satellites operated by the US (DigitalGlobe) and France (Airbus Industries), as well as lower resolution satellites operated by other nations such as South Korea, Japan, and Germany. The best image resolutions are in the range of 31 centimeters and 50 centimeters (ground sample distance per pixel). At such resolutions, it is possible to discern very small changes on the surface that are not obscured, for example by clouds, haze and smoke.

The last four of the five North Korean nuclear tests have been geo-located by two different seismological research teams as having occurred very near Mt. Mantap.⁵ The two most recent tests (6 January 2016 and 9 September 2016) were geo-located and most likely occurred almost directly under the Mt. Mantap peak. **Figure 1** provides a perspective view of Mt. Mantap showing the approximate relative positions of the four most recent underground nuclear tests, along with a cross-section cutaway showing a comparison of calculated burial depths for two assuming a nearly horizontal tunnel

emplacement.* The 30 May 2009 underground nuclear test (geo-location from Pabian and Hecker, 2013⁶) provided a burial depth of ~490 meters and the 9 September 2016 underground nuclear test (geo-location from Gibbons, *et al.*, 2016⁷) suggested an implied intent by the North Koreans to utilize the maximum possible overburden of about 800 meters. The 9 September 2016 test was both the most deeply buried as well as the largest magnitude seismically detected to date (17.8 +/- 5.9 kilotons⁸). As such, it is reasonable to expect that it was a causal factor for the surface disturbances that have been observed directly above the test location and only subsequent to that event.

Geologic Considerations

Mt. Mantap consists of two distinctly different geologic formations.⁹ The mountain core is a batholithic igneous basement rock of either diorite or granite; with the peak rising to an elevation of about 2000 meters above sea level. A nearly horizontal lying sequence of undifferentiated volcanic deposits (e.g., tuffs and pumice) overlays the basement crystalline rock. The source of these volcanic deposits is thought to be volcanic ash from Mt. Paektu, which is located approximately 100 kilometers northwest. The volcanic deposit sequence is approximately 200 meters thick, and is capped by a thin basalt (lava flow) layer at the top of Mt. Mantap. Because the volcanic deposits are more loosely consolidated, they are softer and more easily erodible than the underlying crystalline basement rock or the overlying basalt cap. The volcanic deposits layer also has a slightly steeper slope than the basement rock, and hence is also more prone to erosional scars and landslides. Additionally, as this softer volcanic layer erodes, the overlying basalt cap breaks off at a scarp, forming fields of grey-colored talus/scree downhill, which accumulate in larger piles just below the volcanic deposit layer where the slope decreases slightly.

Within this less stable layer of volcanic deposits, the small surface disturbances, in the form of apparent “spall” and small landslides, were observed on commercial satellite imagery subsequent to the test. **Figure 2** is a schematic diagram illustrating how surface spall can occur at the “free surface” in response to an underground nuclear detonation.

Detecting Visible Changes

To detect changes at the surface, which might be attributable to a particular underground nuclear explosion, high resolution satellite imagery of the area immediately surrounding the event’s seismically detected location should be compared as soon as possible before and after, the event occurs. In the case of the 9 September 2016, test, the latest cloud-free coverage to precede the event was acquired by DigitalGlobe on 7 July 2016; while the first cloud-free imagery following the event was acquired by Airbus Industries on 15 September 2016¹⁰ followed by a 6 October 2016 Digital Globe image.

* Horizontal tunneling for device emplacement is not only a normal engineering practice for underground nuclear testing, but the North Koreans released a propaganda video that displayed a 3D diagram and animation of a horizontal tunnel, which was claimed in the video to have been associated with the 2009 test. For more discussion on that video and tunnel diagram, please see Pabian and Hecker: <http://thebulletin.org/contemplating-third-nuclear-test-north-korea>

The Observed Surface Disturbances

Figure 3 provides an overview perspective of the top of Mt. Mantap as seen on Google Earth from the south looking northward. The pre-test image in **Figure 3** was acquired by DigitalGlobe on 8 May 2016 during a time when the vegetation was not yet in full leaf at this elevation and latitude. (Another more recent pre-test commercial satellite image, which was also entirely cloud-free, was acquired on 7 July 2016. However, at that time, the trees were in full leaf, obscuring the ground below.) A post-test image acquired on 6 October 2016, shown in **Figure 4** for comparison indicates that some new surface disturbances are scattered across the southern flank of Mt. Mantap.

Figures 5 through 7 provide pre- and post-test close-up views of the area located on the southeastern flank of Mt. Mantap near the nonconformity boundary between the upper stratified volcanic deposits and the underlying crystalline basement rock consisting of diorite or granite. A large pre-existing landslide scar is visible on the right of each view.

The small surface disturbances were first visible only after the 9 September 2016 nuclear test. They consist of an expansion of a large pre-existing landslide scar, but may also include some “lofted” rocks (“spall”). However, any “cause and effect” relationship with underground nuclear testing in this particular area remains inconclusive, particularly given the almost one month’s gap between the event and the image shown in **Figure 6**, and the lack of available satellite imagery between the typhoon deluge in late August 2016 and the fifth underground nuclear test.

Figures 8 through 11 provide a sequence of four close-up views of the northwestern corner of Mt. Mantap over the interval between 15 November 2015 and 6 October 2016 showing that a small landslide, of about 750 meters square, first became apparent only after the underground nuclear test conducted by North Korea on 9 September 2016. It should also be noted that this small landslide scar was also faintly observable earlier on commercial satellite imagery from 15 September 2016, which was acquired by the French Airbus Industries satellite, Pleiades, as first published by *38North*.¹¹

Conclusion

The 9 September 2016 North Korean underground nuclear test, which has been seismically geo-located closest to Mt. Mantap peak, was evidently the most deeply buried and had the largest magnitude of Pyongyang’s five tests. It would be expected to generate the kind of disturbances observed on the surface near the peak. The small surface disturbances (identified in the form of small landslides and apparent spall) were seen on publicly available commercial satellite imagery subsequent to the test. Spall is a surface effect closely linked to underground nuclear testing and even deeply buried explosions can cause spall¹². However, a definitive conclusion that the test was the source of the small landslides cannot be reached. They could have been explosion induced, or due to heavy rainfall erosion, or some combination of the two. Without higher frequency imagery coverage (providing the necessary improvement in the temporal resolution) with which to narrow the period of time spanning pre- and post-the occurrence of a nuclear test, it is difficult to unambiguously differentiate all such surface disturbances as being caused solely by nuclear testing at this site.

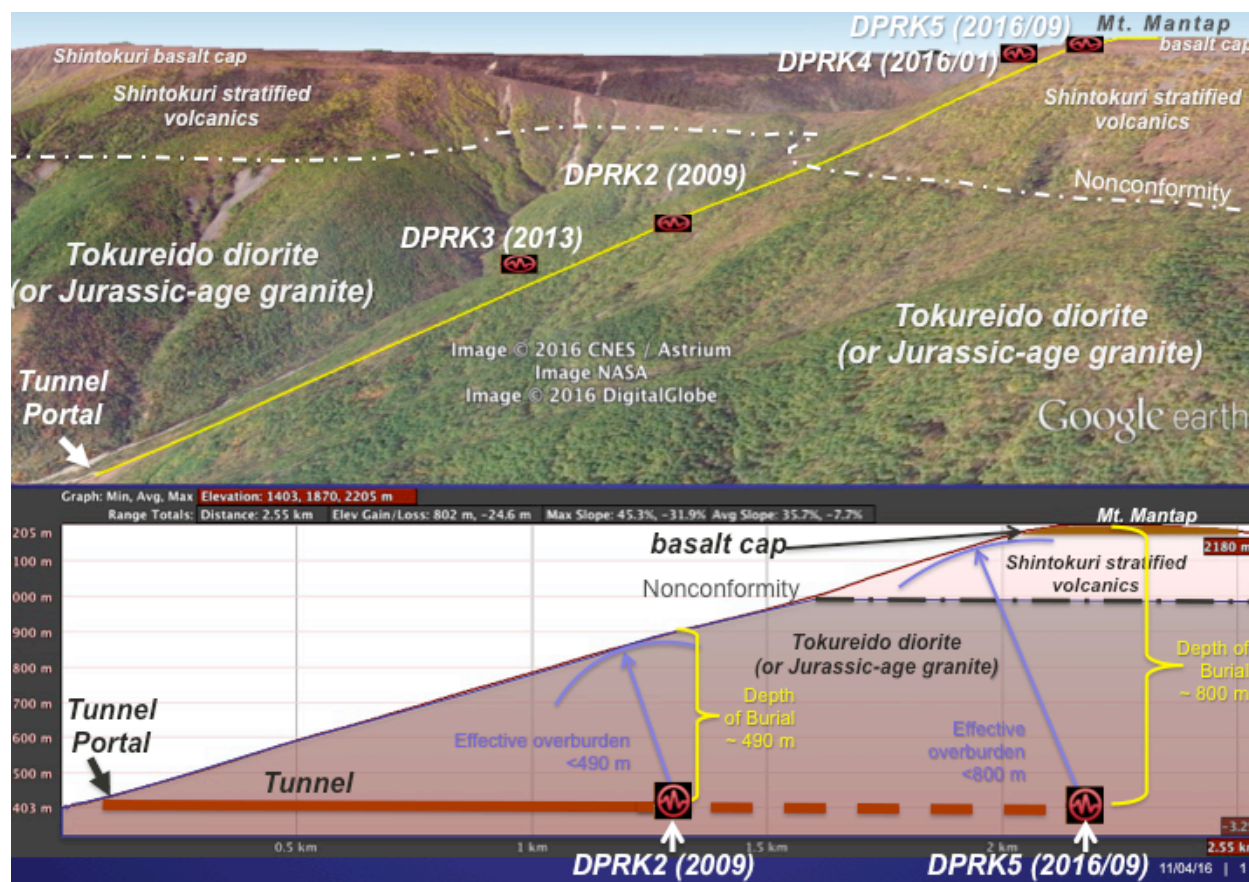


Figure 1: Perspective view of Mt. Mantap showing the approximate relative positions of the four most recent underground nuclear tests, along with a cross-section cutaway showing a comparison of calculated burial depths for two of them given a horizontal tunnel emplacement: the May 2009 underground nuclear test (geo-location from Pabian/Hecker) providing a burial depth of ~490 meters and the September 2016 underground nuclear test (geo-location from Gibbons, et al., 2016) suggesting a North Korean intent to utilize the maximum overburden of about 800 meters.

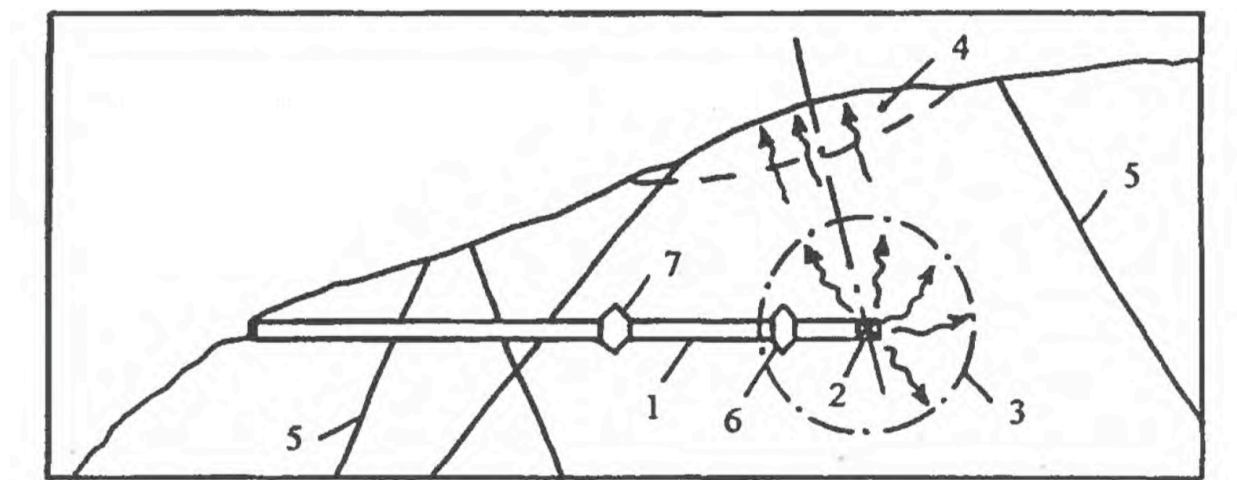


Figure 2: A schematic illustration from a containment study showing various effects from a nuclear detonation involving gas migration through the damaged rock mass: 1- underground works; 2- zero room; 3- damage zone radius; 4- spall zone; 5- tectonic faults; 6 and 7- first and second stemming.¹³ The spall zone is created by the shock wave coming to the free surface closest to the point of detonation. Some of the broken rock in that spall zone can be lofted upward, which generally falls back to the surface at origin.

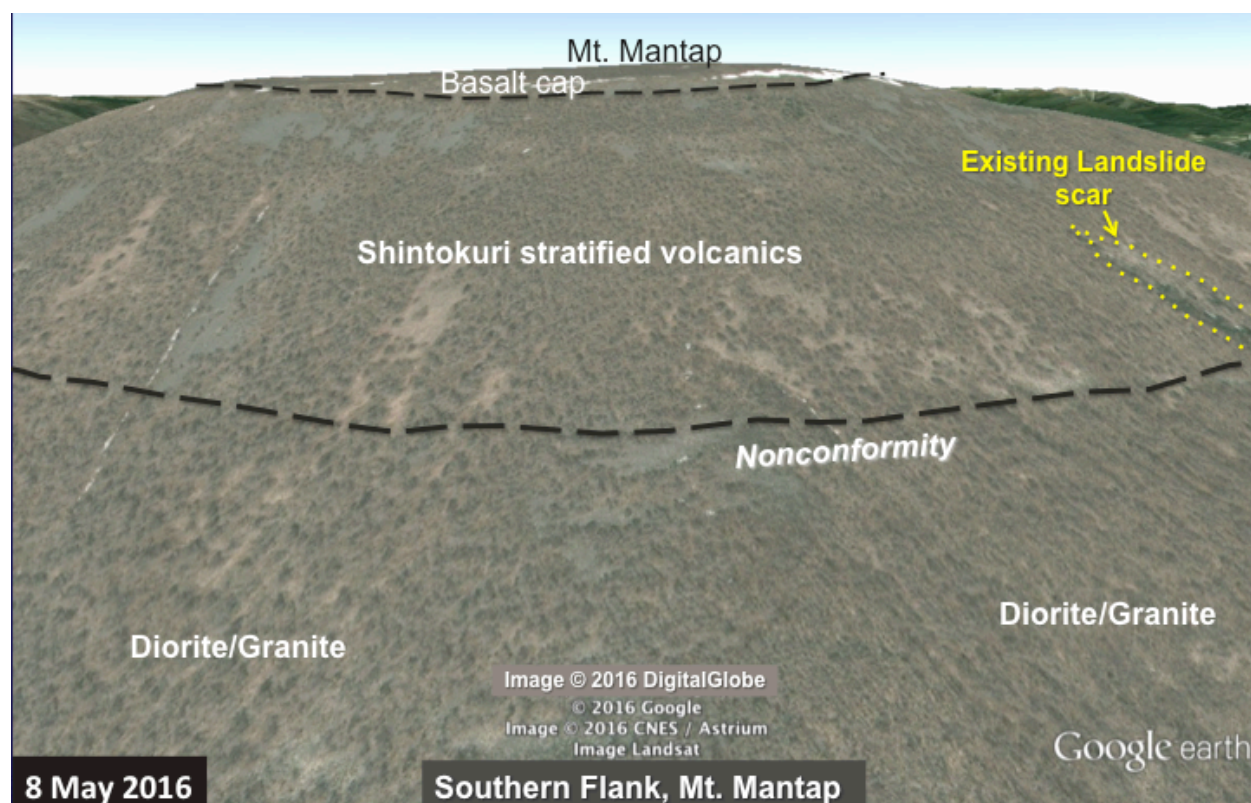


Figure 3: Mount Mantap as viewed from the south, prior to the 9 September 2016 underground nuclear test, Punggye-ri, DPRK

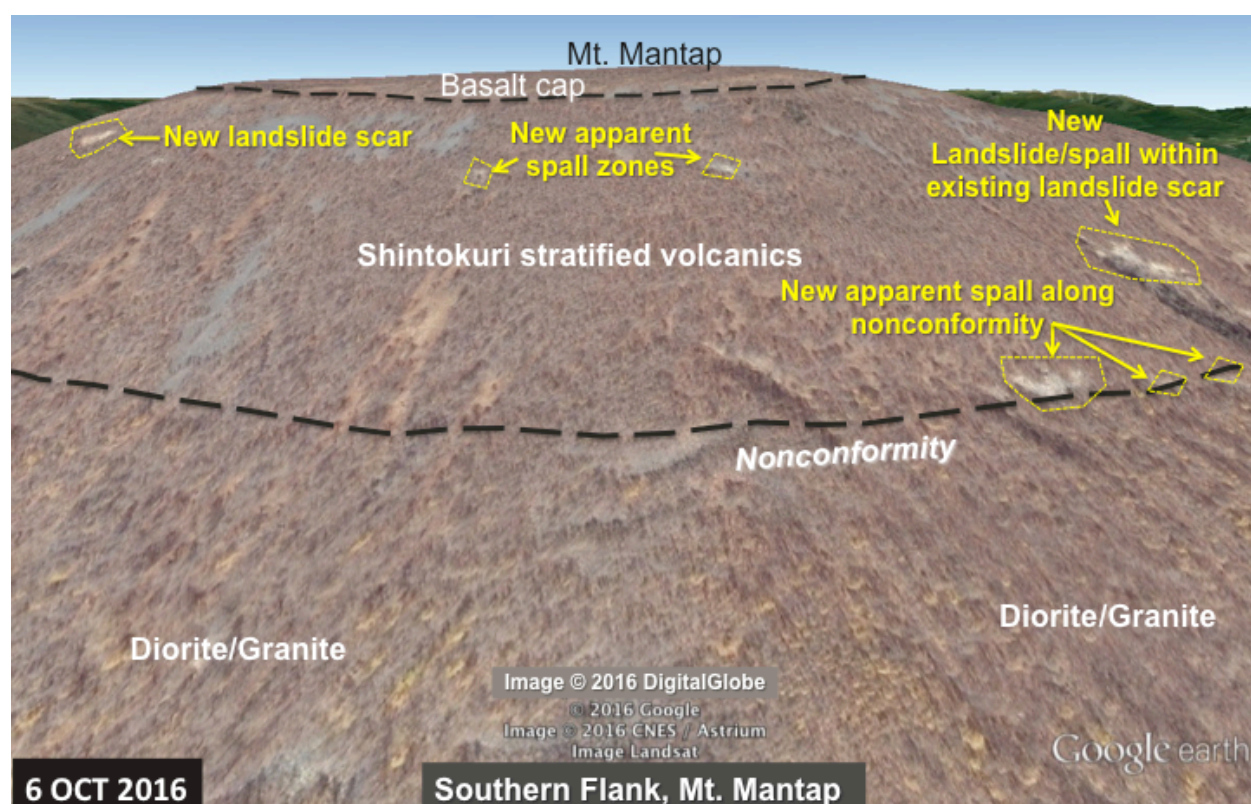


Figure 4: Mount Mantap as viewed from the south after the 9 September 2016 underground nuclear test, Punggye-ri, DPRK showing evidence of post-test surface disturbances.

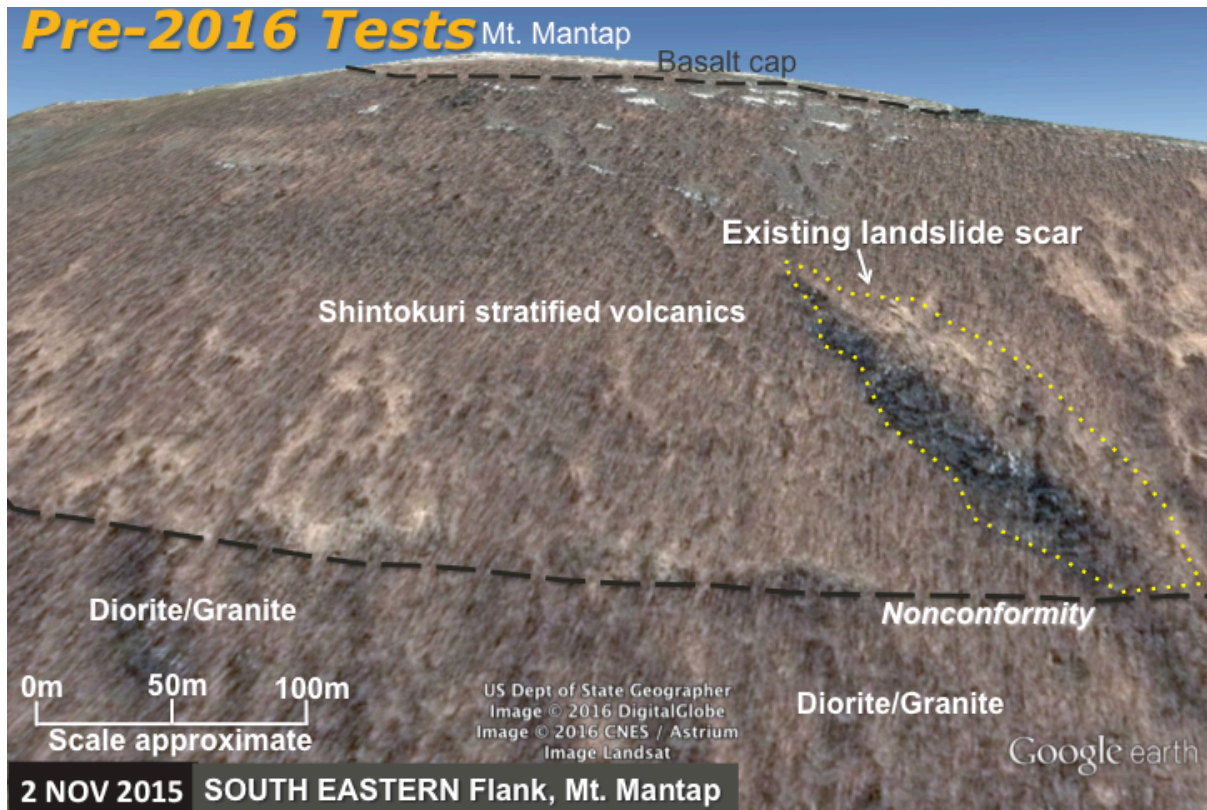


Figure 5

Figure 5: Commercial satellite image of the southeastern flank of Mt. Mantap as it appeared prior to the two underground nuclear tests that occurred in the immediate vicinity in 2016.

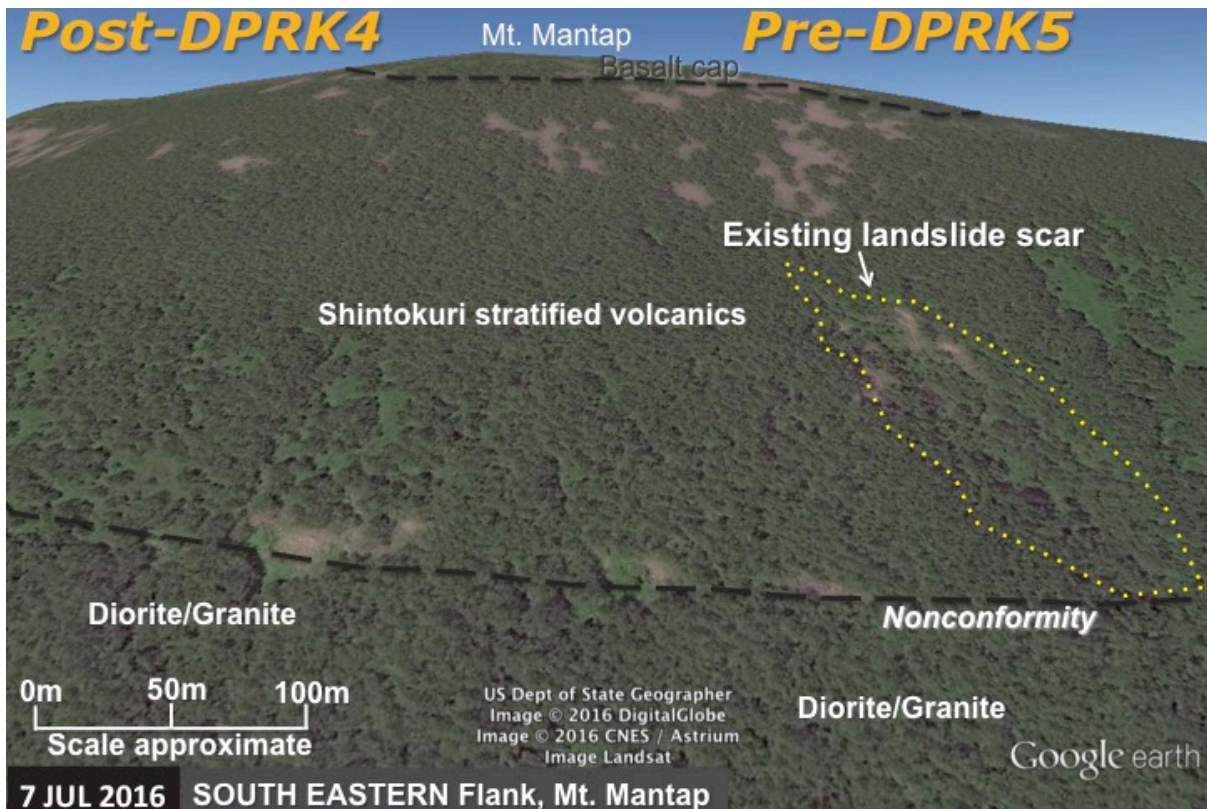


Figure 6

Figure 6: Same view as Figure 4, but after the 6 January 2016 nuclear test and prior to the 9 September 2016 event.

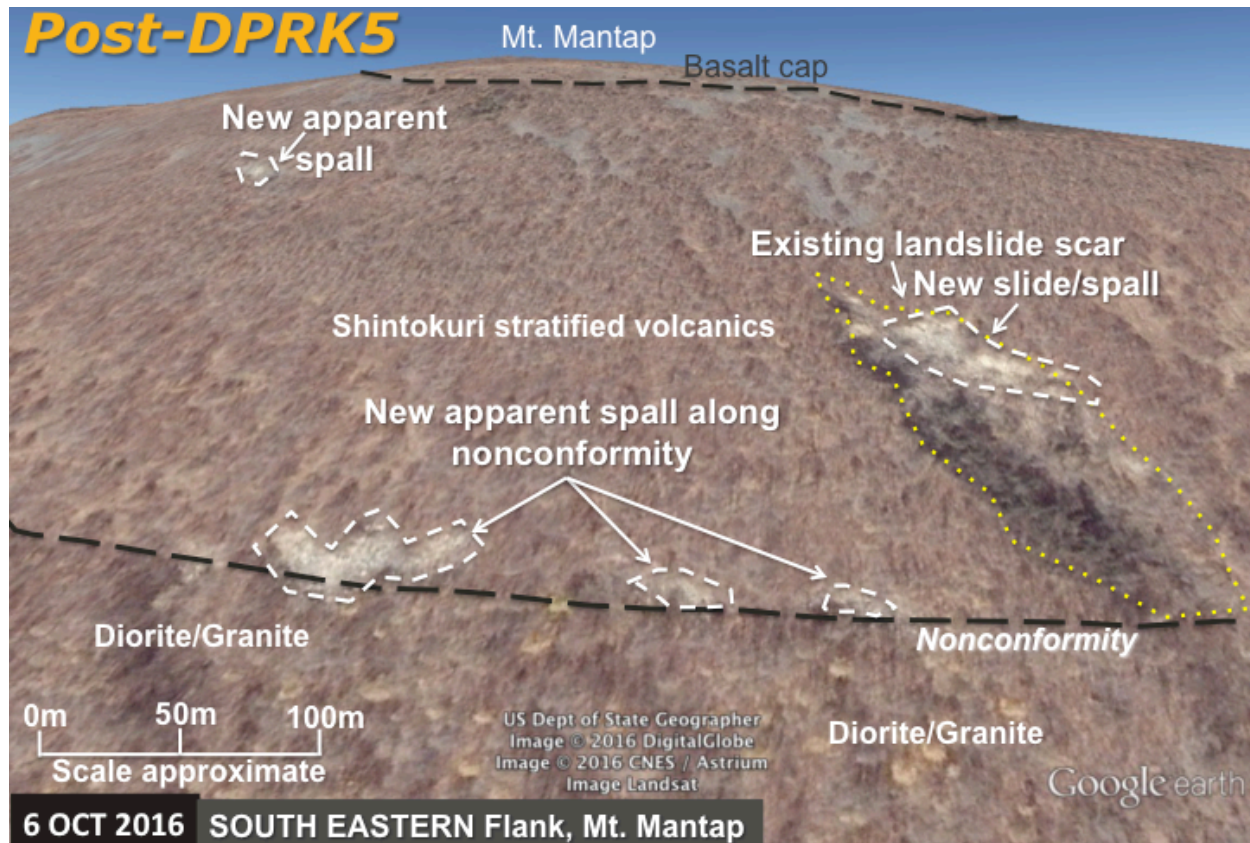


Figure 7: Same view as the two preceding views, but following the 9 September 2016, underground nuclear test showing evidence of surface disturbances that appear to be caused by in-place lofting of loose rock ("spall") and an expansion of an existing slide area that may also include some spall.

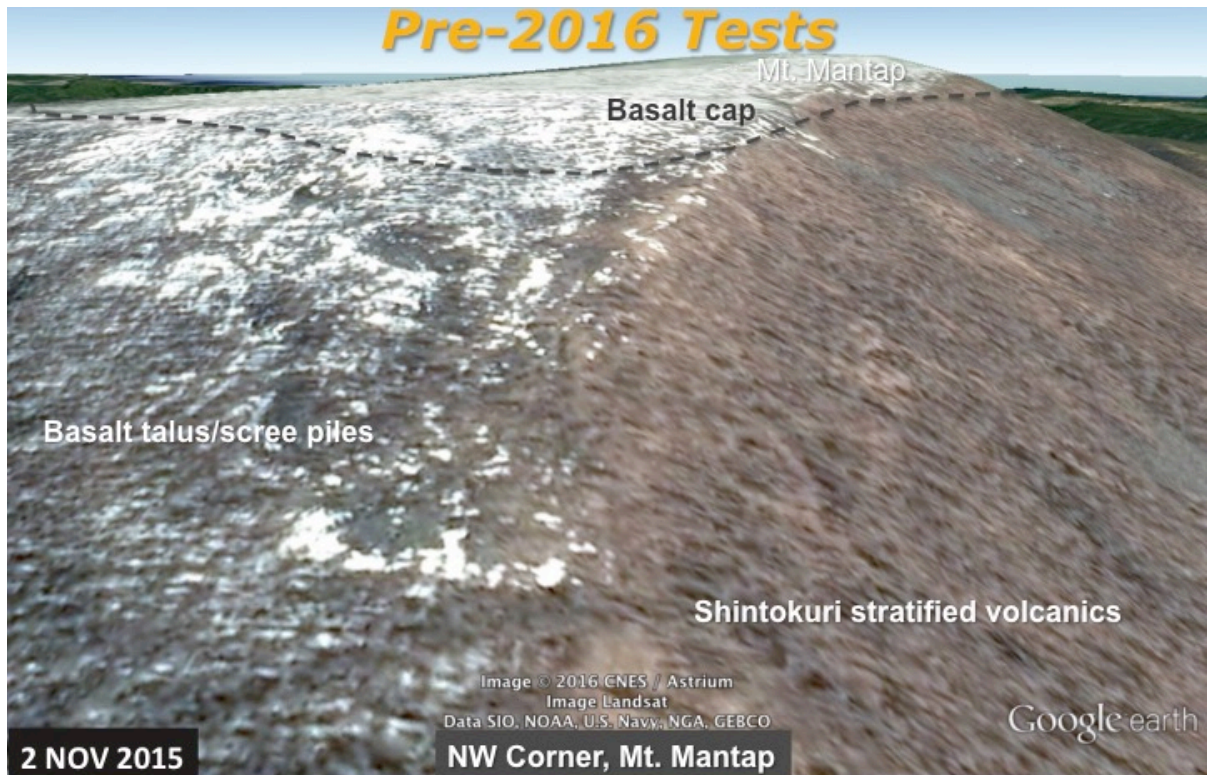


Figure 8

Figure 8: View of the northwest corner of Mt. Mantap (as currently viewed on Google Earth) with satellite imagery from 2



November 2015 prior to the underground nuclear tests conducted by North Korea in 2016

Figure 9: View of the northwest corner of Mt. Mantap on satellite imagery following the 6 January 2016 test and prior to the 9 September 2016.

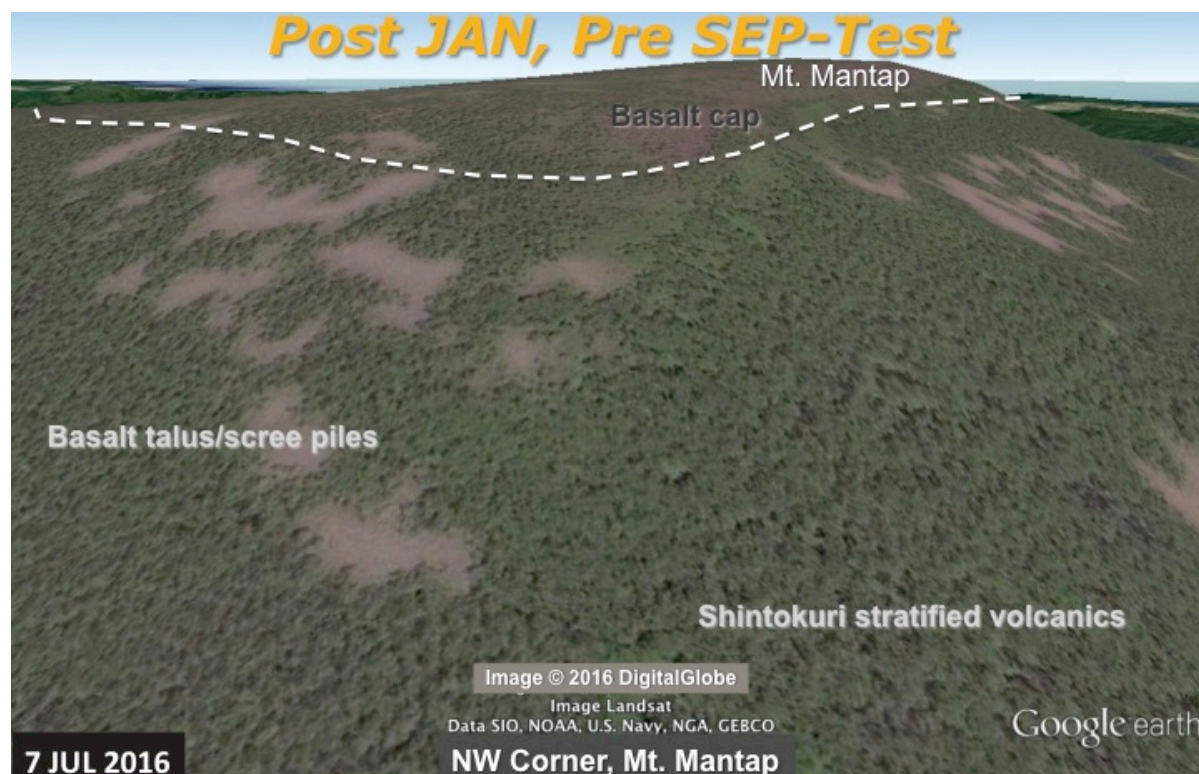


Figure 10: The same view on the last cloud-free commercial satellite image which was acquired prior to the 9 September 2016 underground nuclear test. In this image, the local vegetation is in full leaf, obscuring large portions of the surface beneath.

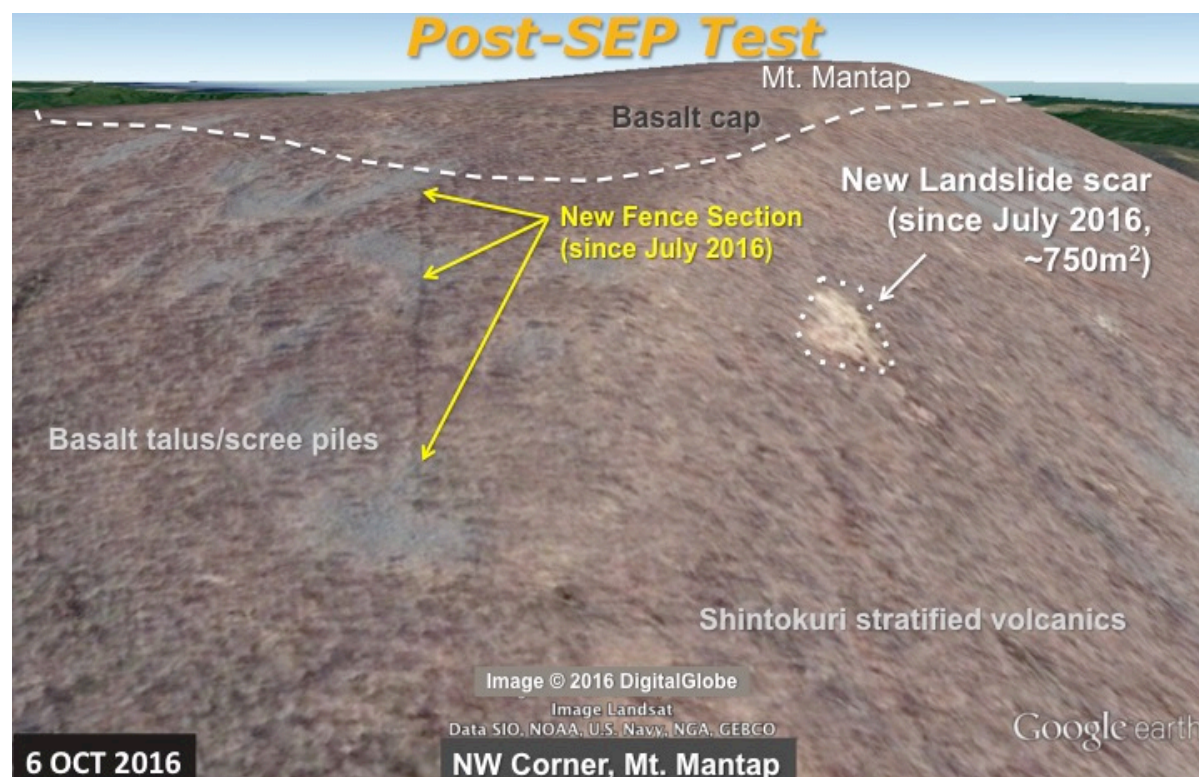


Figure 11: The same view following the 9 September 2016 underground nuclear test revealing the presence of a new landslide scar. (Note: another notable change included the installation of a new segment of perimeter security fencing that was not present on the 7 July 2016 imagery. The fencing appears to extend around Mt. Mantap on its northern side.)

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